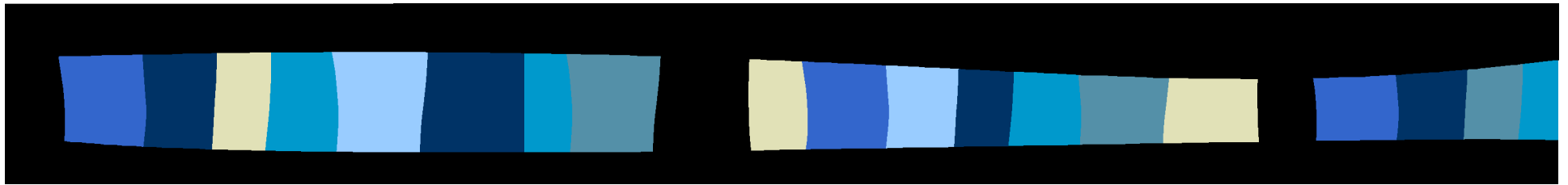


Underground Mining Methods



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Two Main Methods

- Room & Pillar
 - Mostly with continuous miners
- Longwall
 - Develop longwall panels with room & pillar using continuous miners
- About 10% of underground production still comes from drilling & blasting
- Total underground output = 421mt (1997 data)



FIRST, MUST ACCESS THE MINE

- Drift (Adit)
 - Seam outcrops, access from ground level
- Slope
 - Drive incline in rock at up to 16 degrees
 - Allows belt haulage
- Shaft
 - Use: elevators/skids, for: people/coal
 - Use shaft if >1500 feet, economics dictate



LIKE A CITY, OR LARGE BUILDING, SERVICES MUST BE PROVIDED

- Transport people (rail, rubber tired)
- Transport supplies (materials / maintenance)
- Transport product (coal)
- Support roof
- Provide electrical power
- Provide fresh air (& suppress dust)
- Provide fresh water
- Get rid of waste water
- Dispose of trash



ROOM & PILLAR

- Mine “streets & avenues” (entries and crosscuts)
- Leave pillars to support roof (may mine later)
 - Designed by formula
- Plan view-looks like city with “greenbelts”
 - “Greenbelts” are large barrier pillars left to separate work areas
- Use continuous miner



MINE PLAN

- Main entries (7-9 openings)
- Submains (5-7 openings)
- Panels (panel entries, butt entries)
- Rooms (at times)
- Openings limited to 20-ft width
 - **Openings serve as air ducts and travelways**
 - **Return air is isolated from fresh air, two escapeways must be provided from face**
- Longwall panels are solid coal blocks, usually 1000 ft by 10,000 ft, accessed by “gate” roads



ALL SERVICES EXIST TO SUPPORT MINING AT FACE

- Continuous miner - rips coal, using tungsten carbide bits - miner mines at 4-25 t/m and conveys coal into shuttle cars
- Shuttle cars are electric (cable) “trucks” which haul for up to 600 feet or so (usual = 300-400 feet)
 - Haul to feeder-breaker which acts as surge bin/crusher and feed coal onto belt
 - Hold 3-25 tons/load, depending on seam thicknesss and amount of rock mined



FEEDER-BREAKER FEEDS COAL ONTO BELT CONVEYORS

- Conveyors transport coal to surface or into skips for shaft access
 - Usual sizes - 42" to 72"
 - Speeds - 500 - 800 fpm
- Longwall requires largest conveyors
 - 54"-60" usual from face



ROOF BOLTS INSTALLED BY ROOF BOLTING MACHINE

- Roof supported by inserting reinforcing rods
- No one may work under unsupported roof
 - **Cut depths limited to position of shuttle car operator (35' to 40' with remote control miner)**
- When miner place changes, bolter moves in
 - **Bolt 3-6 min/row or 0.75-1.50 min/ft**
 - **Use two bolter operators, twin-boom bolter**
- A few operations attach bolters to miners, bolt as they advance



ROOF SUPPORT

- Insert bolts into the roof on regular pattern (3'-8' length, usually)
 - 4' x 4' or 5' x 5' most common
- Either “glue” (resin) a re-bar bolt in, or
- Use expansion bolt anchors or
- Glue in the anchor only
 - Anchors allow pre-tensioning of bolts



ROOF BOLTS GENERALLY WORK WELL

- Form “reinforced” rock, strong beam
- Or, may “hang” weak rock from stronger overlying rock layer
- Roof fall fatalities are now at 8 -12 per year
 - Half are in violation of the law, under non-bolted roof
 - Roof fall fatalities exceeded 100 per year around 1970



VENTILATION

- Provides oxygen, dilutes methane & dust
 - Methane explosive when at 5-15% concentration
- Most continuous miners have dust scrubber
 - Draw air into ducts at front of miner
 - Efficiency up to 96-97%
- Air directed to working face with brattice cloth (plastic curtains)
- Alternatively, hang tubing & use fan to draw air to face



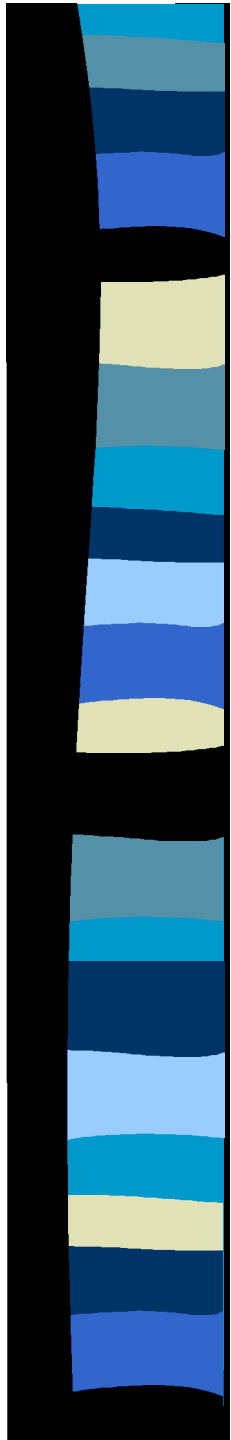
VENTILATION

- Fresh air ventilates one face only, then it is “return” air
 - Separate air streams with concrete block walls or “stoppings”
- Maximum allowable methane content is 1%
- Control major flow with adjustable doors in airways (“regulators”)



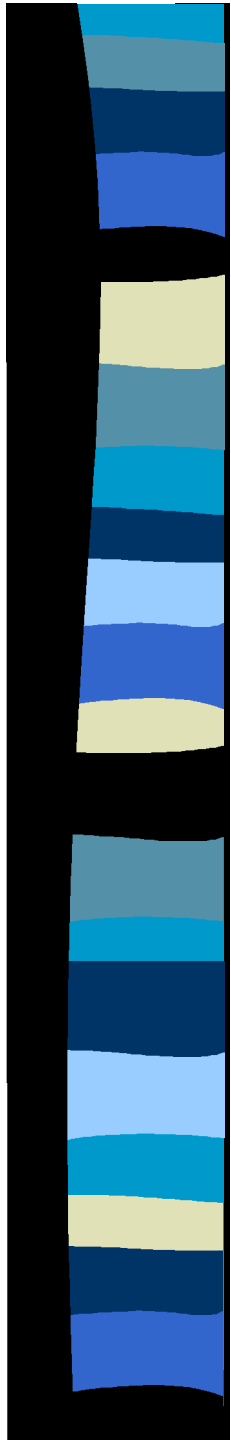
PRODUCTION RATES

- 150 - 400 ft/shift usual, tonnage depends on seam thickness
 - 500 - 2000 tons/shift (usual)
- New miners load at 10 - 25 tpm
- Most continuous miners load only 60-120 min/shift
 - **Load only 12**
 - **10-25% of shift time**



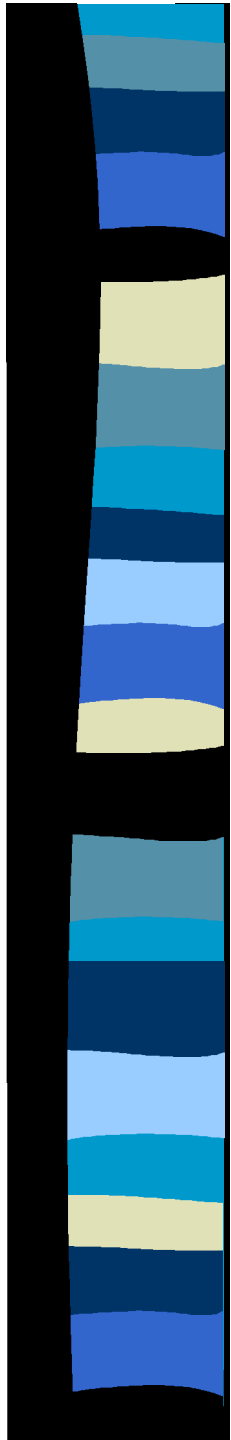
LONGWALL

- More nearly continuous method
- Analogous to “deli meat slicer” (shearer)
 - Shearer mounted on chain conveyor
 - Coal cut falls onto conveyor
- Width of face usually 850 - 1100 ft
 - Depth of slice is 30 - 42 inches
- Behind face supported for 20' or so by steel supports - each 1.50 or 1.75 m wide
 - Each support holds up to 600-1200 tons
- Supports connected to conveyor
 - By pushing, lowering & pulling - can walk conveyor and selves forward



LONGWALL

- Panels (solid block of coal)
 - Usually 850' - 1100' wide & 7500' - 15,000' long
 - Contain 1.5 - 4 mm tons per panel
- Shearers cut at 35 - 65 t/min (2000-4000 tph)
- Output per year = 2 - 6 mm tons
- 6,000 - 20,000 t/day (max = 40,000)
- Cut 200-500 min/day
 - 20% - 45% of time (???)



LONGWALL

- Capital intensive
 - \$30M for face equipment only
 - \$50-80M additional for mine / processing
- Require large, regularly shaped reserve
 - 50M ton minimum
 - Prefer 100-200M tons
- Mine-specific design / limited ability to move to other reserves



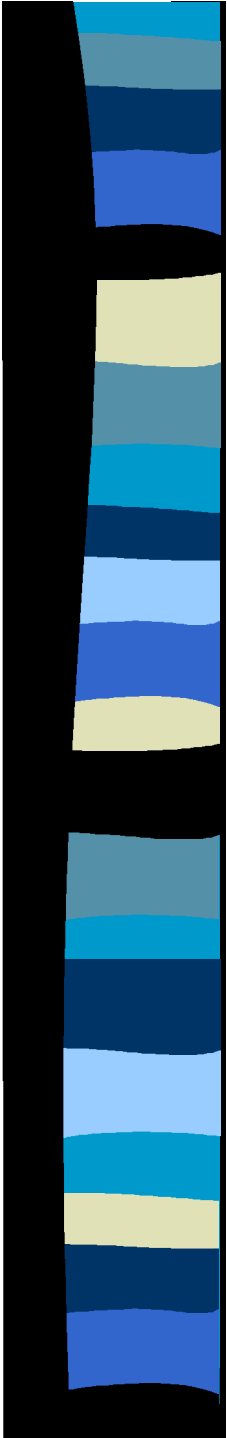
CONTINUOUS MINER SUMMARY

- Capital for section is \$3-5 million
- Flexible, can move readily to other reserves
- One longwall usually requires three continuous miners for development
- Annual output for miner section is 0.3 - 0.8 million tpy



ENVIRONMENTAL

- Longwall strata caves behind supports
 - Surface subsides to maximum of 50-70% of seam thickness
 - “Tilt” area may damage structures, so must provide special support methods at the structures to minimize damage
 - Subsidence trails face position by a few days to a week or two, about 95% occurs in a few weeks



LONGWALL SUBSIDENCE

- Ground water flow is altered
- Some wells lose flow, temporarily or permanently; a few gain
- May need to drill wells deeper
- Connection from near surface to mine is possible if depth to aquifer is less than $40 \times$ seam thickness (240 ft for 6-ft seam)



SUMMARY

- Longwall (45% of UG output from only 60 faces -- average of 3 million tpy each)
 - High output, high capital
 - Low operating cost, 70-80% (?) reserve recovery
 - Low flexibility
- Continuous Miners
 - Medium output, low-medium capital
 - Moderate operating cost, 40-60% reserve recovery
 - High flexibility



SUMMARY

- Can use underground methods in +100 ft of overburden (actual minimum depth depends on whether strip ratio favors surface mining)
 - Roof subject to surface cracks when shallower
- Use longwall in large, thick (mine 6-ft min.), regularly-shaped reserves
 - Only economic method if seam is >1500 ft deep
- Else, use continuous miner and room & pillar
- While best walls far exceed cm productivity, on average, tons per manhour are close



ARCH COAL INC.

Longwall mining machines have revolutionized underground coal mining, enhancing safety and productivity.



Continuous Miners

A full line for all
seam heights